Report for 2005GA82B: Phosphorus Storage and Transport in Headwaters of the Etowah River Watershed

Publications

- There are no reported publications resulting from this project.

Report Follows

Annual Program Report

"Phosphorus Storage and Transport in Headwaters of the Etowah River Watershed"

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Executive Summary

Our research funded by the U.S. Geological Survey through the Georgia Water Resources Research Institute is investigating phosphorus (P) transport in terms of what forms and quantities move through different hydrologic pathways and how such transport relates to P stored in soils and sediments. Our research is being performed in three headwater catchments—two agricultural and one forested—in the upper Etowah River watershed of north central Georgia. Our approach has been to develop watershed P budgets and characterize the concentrations of different forms of P in soils, sediments, and hydrologic pathways. Emphasis is placed on identification and characterization of critical source areas on hillslopes where soils with high concentrations of P are collocated with hydrologic source areas. Methods are based, in part, on high spatial and temporal resolution of field data collection. At this point, our major accomplishment is finding that P loads in the systems we are monitoring are highly variable and can increase by orders of magnitude over short time intervals. Understanding processes at the hillslope and small watershed scales are crucial to developing effective strategies for mitigating transport of P to downstream waterbodies.

(1) RESEARCH

In most watersheds that have undergone human development, the mass of phosphorus (P) transferred hydrologically over and through the soils and into streams and rivers greatly exceeds what would be transferred naturally. In the southeastern U.S., accelerated loads of P entering lakes and reservoirs used for drinking water and recreation stimulates growth of nuisance phytoplankton algal communities. Seasonal cycles of growth and subsequent decay of the algal communities degrade drinking water supplies, deplete oxygen for aquatic life, and cause imbalances in overall aquatic ecosystem function. The processes that regulate hydrologic transfer of P are complex and highly variable. Effective management of P through best management practices (BMPs) is directly linked to our understanding of how sources, pathways, and mobilization mechanisms that lead to P transfer and delivery are integrated at the watershed scale.

Our research funded by the U.S. Geological Survey (USGS) through the Georgia Water Resources Research Institute (WRRI) is evaluating how amounts and forms of P in storage and in different hydrologic pathways relate to the amounts and forms of P exported. Our research is being performed in three headwater catchments—two agricultural and one forested—in the upper Etowah River watershed of north central Georgia. The approach is to develop watershed P budgets and characterize the concentrations of different forms of P in soils, sediments, and hydrologic pathways. Emphasis will be placed on identification and characterization of critical source areas (CSAs) (i.e. Gburek and Sharpley (1998), Pionke et al. (2000)) which are soils with high concentrations of P are collocated with hydrologic source areas. Methods will be based in part on high spatial and temporal resolution of field data collection. Our research is aimed at answering the following questions:

(1) How is P yield related to the amount of P stored in the watershed?
(2) How is P yield related to present inputs of P?
(3) How do forms and concentrations of P vary among different hydrologic pathways?
(4) What are the primary hydrologic and chemical controls affecting P yield?

Our research augments a separate 2-year study by a UGA research team funded by the U.S. Department of Agriculture. In that study, 12 headwater streams within the upper Etowah River watershed, predominated by either agricultural or forested land use types, are being monitored to generate information to be used to explore options for point/non-point pollution trading of P. Monitoring methods include continuous streamflow measurement using H-flumes and a combination of systematic, biweekly grab samples coupled with storm sample collection using ISCO autosamplers. Water quality samples are analyzed for total P (TP), dissolved (<0.45 µm) reactive P (DRP), total suspended solids, and turbidity. Water quality and flow data are used to estimate both short-term (i.e. storm-specific) and long term (annual) P loads and yields.

Interim results from the UGA Etowah study are illustrated in Figures 1-3 at the end of this report section. Results for grab samples, which are typically collected during baseflow conditions, are differentiated from storm samples, which are typically collected via ISCO autosamplers. Median concentration, median load, and median unit-area load (yield) for TP and DRP are depicted in Figures 1-3, respectively. The three forested streams are represented by Sites 1, 2, and 3. All other sites (4 thru 12) represent agricultural land use conditions. Key results for TP only are discussed here. Median TP concentrations for grab and storm samples from forested watersheds range 3.4 to 7.6 and 3.8 to 10 ug-P/L, respectively. For agricultural watersheds, median TP concentrations for grab and storm samples range 3 to 298 and 30 to 1,970 ug-P/L, respectively. Highest P concentrations, loads, and unit-area loads are associated with agricultural watersheds #5, 6, and #12. These three watersheds are the smallest agricultural watersheds being monitored.

From the UGA Etowah study, forested site #2 plus agricultural sites #5 and #12 were selected for our current USGS/WRRI-funded research. Forested site #2 was chosen because of its ease for access for monitoring of in-stream water quality, hillslope hydrologic conditions, and atmospheric deposition. At sites #5 and #12, phosphorus concentrations, loads, and yields are among the highest of the 9 agricultural streams being monitored under the UGA study. This suggests that they are likely to be among the most critical in terms of support needed to guide future nutrient management. As stated previously, effective management of P through best management practices (BMPs) is directly linked to our understanding of how sources, pathways, and mobilization mechanisms that lead to P transfer and delivery are integrated at the watershed scale.

Our study plan remains largely the same as originally proposed. Development of P budgets will require knowledge of P inputs, outputs, and storage. Attempts will be made to directly monitor all P inputs including manure application and wet and dry forms of atmospheric deposition. Wet-deposition will be monitored using rain-activated deposition samplers. One sampler will be installed at each of the three watersheds. Methods will be adapted from the National Atmospheric Deposition Program (NADP) (Dossett and Bowersox 1999) with the exception that our monitoring equipment will be intentionally sited near confined animal feeding operations. Dry deposition monitoring will be based on sampling of foliage and inert surfaces (i.e Lindberg and Lovett 1985) and/or throughfall (i.e. Argo 1995). Attempts may be made to collect samples of runoff from roofs of poultry houses. Concentrations of P in atmospheric deposition samples are expected to be low, highly variable, and subject to measurement-type errors. Personnel with the NADP laboratory in Illinois have offered analytical support. Samples of different forms of manure will be collected for laboratory analysis. This will require coordination with farmers and landowners. Information on the volume, rate, frequency, and place of application will be gathered from farmers.

Streamflow outputs will be measured through the current UGA Etowah project. However, modifications will be incorporated that include higher frequencies of sample collection and laboratory analyses that encompass the full range of P forms. Characterization of streamflow biologically-available P via anion-exchange resin (AER-P) strips and/or filtration media smaller than 0.45 um are currently being explored.

Estimation of P in storage in each watershed must account for P held by soils, sediments, and vegetation. Accounting for uptake and recycling of P by vegetation will be based on methods used by Harned et al. (2004) and other studies. The quantity of P in storage by soil will be estimated via collection of soil samples at different depths on a grid basis throughout the catchments. At each grid point, samples will be collected at multiple depths. At the soil surface of each gridpoint, the degree of vegetative cover will be characterized. In the soil subsurface at each gridpoint, the depth to the B_t horizon, and soil redoximorphic features at gridpoints will be observed as a means of attempting to elucidate the potential for interflow or induction of variable source area runoff. Geostatistical methods will be used to identify hotspots and overall spatial variability of soil P. Soil sampling along transects at each site has been performed to elucidate variability in soil P concentrations as a function of hillslope position, soil depth, and distance between sample points. This will guide future grid-based soil sampling and subsequent geostatistical analyses. Stream sediment samples will be collected from the upper 2-3 centimeters of depositional zones in each stream. Composite samples will be collected from different depositional zones. Soil and sediment samples will be analyzed for TP, water-soluble P, AER-P, and degree of P saturation.

As stated earlier, this study will emphasize identification of CSAs. Identification of CSAs will be attempted by utilizing information gained through surface and subsurface soil monitoring (i.e. high soil P concentrations, redoximorphic features, shallow depth to groundwater or B_t layer, and/or poor vegetative cover) described in the previous paragraph combined with topographic surveys. These surveys may either be quantitative or qualitative and may be based on the assumption that a CSA is characterized by variable source area hydrology. Variable source areas typically are located on the lower portion near or along stream channels where steeper hillslopes converge to flat, topographic lows (i.e. $\ln A/\tan \beta$ concept).

Soil monitoring and attempts to identify CSAs will guide placement of instrumentation for monitoring hydrologic pathways. For monitoring purposes, pathways to be sampled will include 1) Horton overland flow, 2) interflow, 3) variable source area runoff, and 4) shallow groundwater. An assortment of surface collectors, drop collectors, piezometers, and suction cup lysimeters will be used to characterize different P forms in these pathways. Piezometers, instrumented with data-recording capacitance probes, will be placed in both near-stream areas and stream channels to determine the hydraulic gradient of shallow groundwater. Streamflow and shallow groundwater will be continuously monitored for temperature, pH, and oxidation-reduction potential (ORP) using thermistors, pH probes, and ORP probes linked to dataloggers.

Attempts will be made to monitor P transfer in different hydrologic pathways during different flow regimes and before and after poultry litter application. A combination of instrumentation and on-the-ground field staff will be used to collect intrastorm data from in-stream and different hydrologic pathways. This monitoring data will be used to describe hydrochemical response as a function of soil P levels and other critical factors including water storage and antecedent moisture conditions. An underlying approach for the hydrologic monitoring component of this study is short-duration (i.e. storm event duration), high frequency observations in line with Kirchner et al. (2004).

Concentrations of P forms in different hydrologic pathways may be compared using end-member mixing (EMMA) or principal component analysis (PCA). Past surface water chemistry studies using these methods (i.e. Burns et al. (2001), Hooper (2003)) have been based on conservative solutes to differentiate between and estimate contributions from different sources of streamflow. Because P can be expected to change form along its course from the hillslope to the stream, it may be necessary to include other solutes in the analytical program. Solutes that may warrant consideration may include chloride, calcium, sulfate, or perhaps iron or silica.

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FIGURES

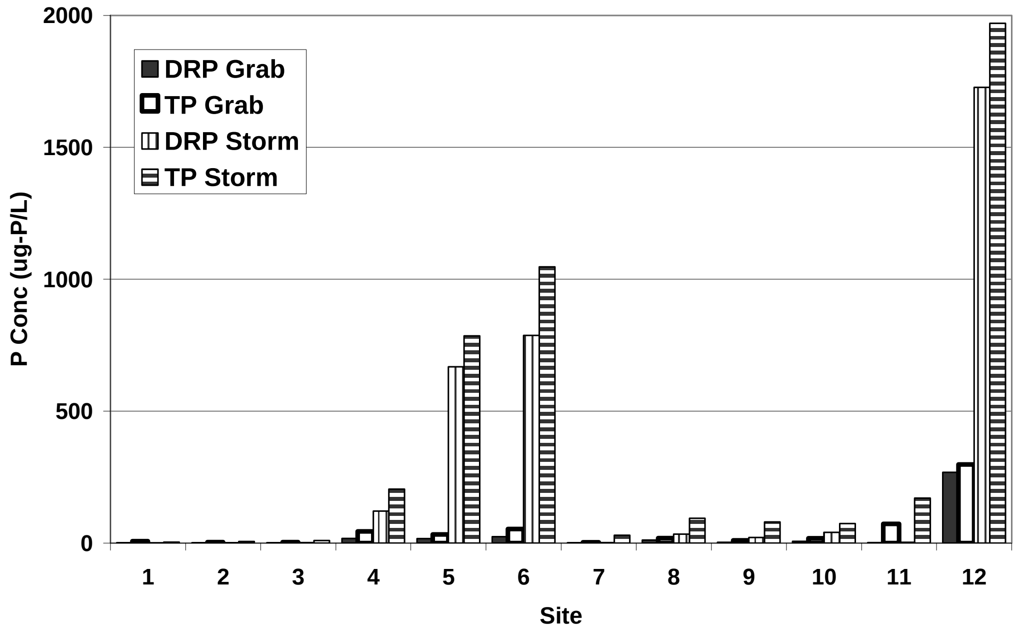

Figure 1. Median total phosphorus concentration by site

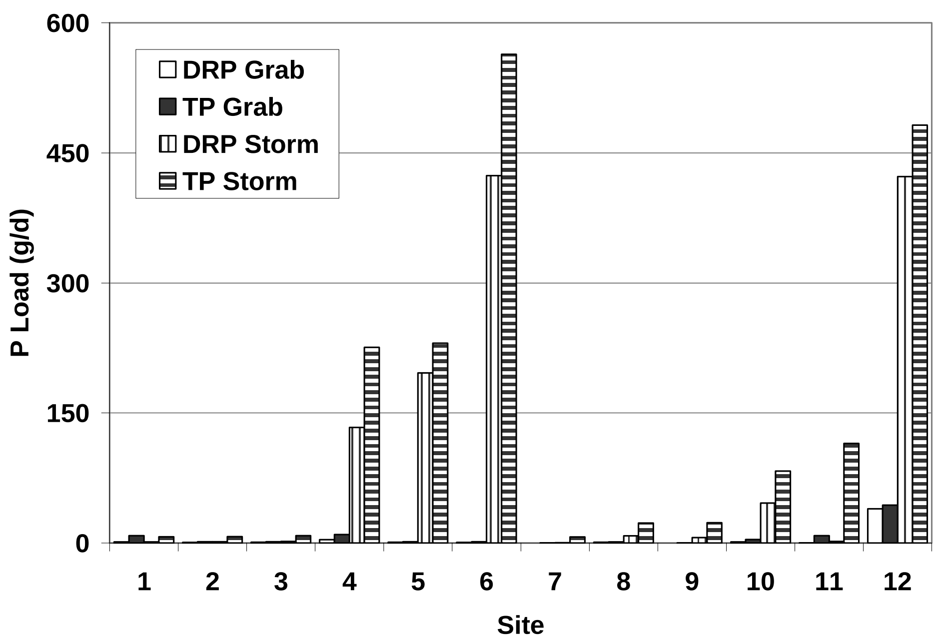

Figure 2. Median instantaneous total phosphorus load by site

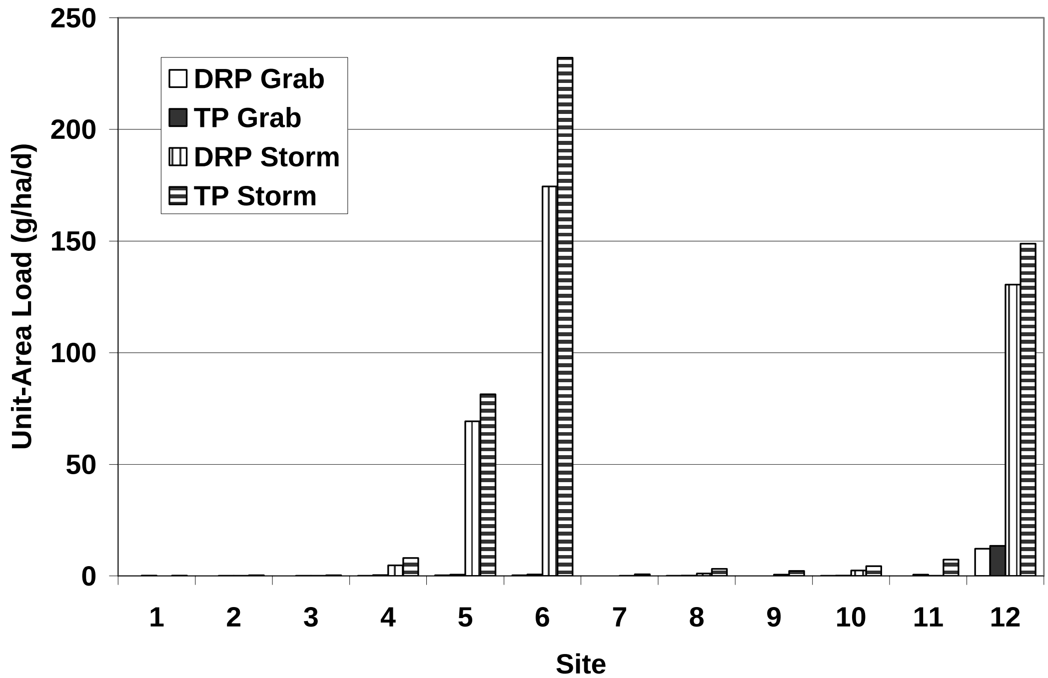

Figure 3. Median unit-area total phosphorus load by site

(2) PUBLICATIONS

Romeis, J. and R. Jackson. 2005. Evaluation of total phosphorus in the Altamaha-Ocmulgee-Oconee River basin. Proceedings of the Georgia Water Resources Conference, April 25-27, Kathy Hatcher, Ed, Institute of Ecology, University of Georgia, Athens, GA.

Romeis, J.J. and C.R. Jackson. 2005. Evaluation of total phosphorus in the Altamaha-Ocmulgee-Oconee (AOO) River Basin, Georgia. Proceedings of the 2005 Annual Conference of the American Water Resources Association, November 7-10, Seattle, WA

(3) INFORMATION TRANSFER PROGRAM

a. Research was presented at the annual conference of the American Water Resources Association conference in November 2006 and at the Georgia Water Resources Conference in April 2006.

b. Meetings were held among poultry and cattle farmers, Etowah River watershed stakeholders, and University of Georgia scientists. Results of monitoring activities have been reported to farmers and landowners.

c. Results of research will be presented in peer-reviewed journal articles.

d. Results will be used to develop a nonpoint nutrient trading program with the goal of reduced phosphorus loading to the Etowah River and Lake Allatoona.

(4) STUDENT SUPPORT

One Ph.D graduate student in the Warnell School of Forestry and Natural Resources at the University of Georgia was supported.

(5) STUDENT INTERNSHIP PROGRAM

Not applicable.

(6) NOTABLE ACHIEVEMENTS AND AWARDS

None.